

Appl. No. : 10/550,188
Amdt. Dated: May 7, 2008
Reply to Office Action of February 7, 2008

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Amendments to the Specification:

On page 1, before line 2, please insert the following text:

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is derived from PCT application PCT/EP2004/003010 filed March 22, 2004 and claims priority from UK patent application GB 0306724.6 filed March 24, 2003.

BACKGROUND OF THE INVENTION

Field of the invention

On page 1, before line 3, please insert the following Title:

Description of Related Art

On page 1, beginning with line 11, please insert the following paragraphs:

Referring to Figures 1 to 3, the measurement of optical wavelength using coarse and fine wavelength dependent filters is known from, for example, GB 0223448.2 for characterisation of tuneable lasers. A known arrangement 10 is shown in Figure 1, in which a laser beam 11 from the tuneable laser 12 is split by a branched waveguide to direct the light beam under test to four pathways 131,132,133,134 leading respectively to: a reference photodiode 141; a coarse, monotonic or linear spectral filter 15 for the wavelength band of interest with an output to a second photodiode 151; and two periodic transmission filters 16,17, the respective outputs of which vary periodically with wavelength across free spectral ranges, having outputs to third and fourth photodiodes 161,171, respectively. Typically the periodic filters 16,17 are Fabry Perot etalon filters having 50 GHz and 5 GHz free spectral range respectively, as shown in Figure 2.

The coarse feature extraction filter 15 is a dielectric multilayer coating on a glass substrate with a monotonic frequency response across the C-band; while the medium and fine frequency identification filters 16, 17 are, for example, each formed from two parallel 95% dielectric mirrors with flat response.

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Characteristics of the filters are shown in Figure 2, in which a first plot 21 shows a linear response of the coarse filter 15, a second plot 22 shows a periodic response of the first periodic filter 16 with a free spectral range of 50 GHz and a third plot 23 shows a periodic response of the second periodic filter 17 with a free spectral range of 5 GHz.

In use, the wavelength of an emitted beam is determined approximately with the linear filter 15 by determining transmissivity of the filter at the given wavelength by comparing the power of the reference beam, as measured with the first reference photodiode 141, with the power of the beam transmitted through the filter 15 as measured by the second photodiode 151. The wavelength is determined with sufficient precision, e.g. is found to be in the range 24 shown in Figure 2, to determine on which peaks 221, 231 of the periodic filter transmission curves 22, 23 the measured wavelength lies. As shown in Figure 3, knowing on which peaks the wavelength lies, the wavelength 241 may be determined unambiguously from the outputs of the third and fourth photodiodes 161, 171.

On page 1, before line 13, please insert the following Title:

BRIEF SUMMARY OF THE INVENTION

On page 4, before line 26, please insert the following Title:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

On page 6, before line 1, please insert the following Title:

DETAILED DESCRIPTION OF THE INVENTION

On page 6, line 1 through line 31, please delete the following text:

~~Referring to Figures 1 to 3, the measurement of optical wavelength using coarse and fine wavelength dependent filters is known from, for example, GB 0223448.2 for characterisation of tuneable lasers. A known arrangement 10 is shown in Figure 1, in which a laser beam 11 from the tuneable laser 12 is split by a branched waveguide to direct the light beam under test to four pathways 131, 132, 133, 134 leading respectively to: a reference photodiode 141; a coarse, monotonic or linear spectral filter 15 for the wavelength band of interest with an output to a second photodiode~~

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~~151; and two periodic transmission filters 16,17, the respective outputs of which vary periodically with wavelength across free spectral ranges, having outputs to third and fourth photodiodes 161,171, respectively. Typically the periodic filters 16,17 are Fabry-Perot etalon filters having 50 GHz and 5 GHz free spectral range respectively, as shown in Figure 2.~~

~~The coarse feature extraction filter 15 is a dielectric multilayer coating on a glass substrate with a monotonic frequency response across the C band; while the medium and fine frequency identification filters 16,17 are, for example, each formed from two parallel 95% dielectric mirrors with flat response.~~

~~Characteristics of the filters are shown in Figure 2, in which a first plot 21 shows a linear response of the coarse filter 15, a second plot 22 shows a periodic response of the first periodic filter 16 with a free spectral range of 50 GHz and a third plot 23 shows a periodic response of the second periodic filter 17 with a free spectral range of 5 GHz.~~

~~In use, the wavelength of an emitted beam is determined approximately with the linear filter 15 by determining transmissivity of the filter at the given wavelength by comparing the power of the reference beam, as measured with the first reference photodiode 141, with the power of the beam transmitted through the filter 15 as measured by the second photodiode 151. The wavelength is determined with sufficient precision, e.g. is found to be in the range 24 shown in Figure 2, to determine on which peaks 221, 231 of the periodic filter transmission curves 22, 23 the measured wavelength lies. As shown in Figure 3, knowing on which peaks the wavelength lies, the wavelength 241 may be determined unambiguously from the outputs of the third and fourth photodiodes 161, 171.~~

On the page immediately following the claims, please insert the following:

ABSTRACT OF THE DISCLOSURE

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05/08/2008 PCHDMR 00000024 191351 10550188

Amendments to the Claims:01 FC:1201 420.00 DA
02 FC:1202 150.00 DA

Claims 1-34 (Cancelled)

35. (Previously presented) An optical wavelength meter for measuring an optical wavelength of an optical beam comprising:

- a) coarse optical filter means and first optical power measurement means for measuring output of the coarse optical filter means and second optical power measurement means for measuring an unfiltered reference beam for coarse wavelength measurement;
- b) fine optical filter means comprising first and second periodic optical filters in quadrature having a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first filter coincide with substantially linear ranges between peaks and troughs of the second filter, and third and fourth optical power measurement means for measuring output of the first and second periodic optical filters in quadrature for fine wavelength measurement, respectively;
- c) beam splitting means for splitting the optical beam between the unfiltered reference beam and the coarse and fine optical filter means;
- d) synchronized clock signal measurement means for synchronized measurement of the output of the first, second, third and fourth optical power measurement means; and
- e) processing means for determining the optical wavelength of the optical beam from a predetermined transmissivity-wavelength relationship of the coarse filter and the first and second optical power measurement means for coarse wavelength measurement and from predetermined transmissivity-wavelength relationships of the first and second periodic optical filters and at least one of the third and fourth optical power measurement means for fine wavelength measurement.

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36. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the coarse optical filter means comprises a linear spectral filter.
37. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the coarse optical filter means comprises a dielectric multilayer coating on a glass substrate.
38. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the periodic optical filters comprise at least one of a Fabry Perot filter, a Fizeau filter, a fibre Bragg grating and a photonic crystal.
39. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein a phase offset between the first and second periodic optical filters in quadrature is tuned by angle, temperature or pressure using a piezoelectric transducer.
40. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein reflectivity of the periodic optical filters is substantially 25%.
41. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the periodic optical filters have a free spectral range of substantially 50 GHz instead of substantially 100 GHz.
42. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the periodic optical filters are parallel or wedge quartz etalons.
43. (Previously presented) An optical wavelength meter as claimed in claim 35, further comprising calibration filter means and calibration filter output power measuring means.
44. (Previously presented) An optical wavelength meter as claimed in claim 43, wherein the calibration filter means comprises an etalon filter.

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45. (Previously presented) An optical wavelength meter as claimed in claim 44, wherein the etalon filter has precisely set or controllable free spectral range.
46. (Previously presented) An optical wavelength meter as claimed in claim 44, wherein the free spectral range of the etalon filter is controllable and preset by rotation adjustment or temperature.
47. (Previously presented) An optical wavelength meter as claimed in claim 44, wherein free spectral range of the calibration etalon filter differs just sufficiently from the free spectral range of the periodic optical filters that the calibration etalon filter is in phase only at top, middle and bottom wavelengths of a range of measurements of interest to obtain co-incident or Vernier-like maximum power at those wavelengths.
48. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein at least one of the optical power measurement means comprises a photodiode.
49. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein the synchronised clock signal measurement means comprises master module and slave modules to trigger measurement and read output of the optical power measurement means.
50. (Previously presented) An optical wavelength meter as claimed in claim 49, wherein the synchronised clock signal measurement means enables 40,000 points on each of a plurality of channels to be read in 2.5 seconds.
51. (Previously presented) An optical wavelength meter as claimed in claim 35, wherein, the synchronised clock signal measurement means enables 1,000 to 10,000 wavelength measurements/second.
52. (Previously presented) An optical wavelength meter as claimed in claim 35, having a precision of substantially 2 picometers or substantially 250 MHz.

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53. (Previously presented) An optical wavelength meter as claimed in claim 35, arranged to make wavelength measurements in at least one of optical C-band, optical L-band and optical S-band.
54. (Previously presented) An optical wavelength meter as claimed in claim 35, further comprising temperature control means for stabilising optical components thereof.
55. (Previously presented) An optical wavelength meter as claimed in claim 54 wherein the temperature control means comprises a thermistor or thermocouple and fan cooling or Peltier temperature elements.
56. (Previously presented) An optical wavelength meter as claimed in claim 35, adapted for external triggering for synchronisation with external instrumentation.
57. (Previously presented) An optical wavelength meter as claimed in claim 35, arranged to measure infrared or visible wavelengths.
58. (Previously presented) A method of determining wavelength of an optical beam comprising:
 - a) splitting the optical beam into first, second, third and fourth sub-beams;
 - b) presenting the first sub-beam to reference first photodetector means;
 - c) presenting the second sub-beam to coarse filter means having an output to second photodetector means;
 - d) presenting the third sub-beam to a first fine periodic filter having an output to third photodetector means;
 - e) presenting the fourth sub-beam to a second fine periodic filter having an output to fourth photodetector means, wherein the first fine periodic filter and the second fine periodic filter are in quadrature and have a

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finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first fine periodic filter coincide with substantially linear ranges between peaks and troughs of the second fine periodic filter;

- f) using synchronized clock signal measurement means to read outputs from the first, second, third and fourth photodetector means;
- g) identifying from predetermined transmissivity-wavelength characteristics of the coarse filter means and the first and second photodetector means outputs a limited range of wavelength in which the wavelength of the optical beam lies, to determine from their predetermined transmissivity-wavelength sensitivities which of the first fine filter and the second fine filter has a greater sensitivity to wavelength in that limited range; and
- h) using predetermined transmissivity-wavelength characteristics of the first or second fine filter having the greater sensitivity in the limited range of wavelength and the corresponding third or fourth photodetector means output, corresponding to the fine filter means having the greater sensitivity, to determine the wavelength of the optical beam.

59. (Currently amended) A method as claimed in claim 58, comprising the further steps of:

- a) providing a calibration etalon filter with conventional Airy function transmitting only at a reference wavelength for calibration having a common maximum with the first and second fine periodic filters respectively at a limited number of wavelengths within range;
- b) providing a broadband light source or a tuneable laser tuned to the reference wavelength; and

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- c) calibrating the processed readout from fine periodic filters to the reference wavelength of the calibration etalon filter.
- 60. (Cancelled).
- 61. (Currently Amended) A method as claimed in claim 59, wherein step a) additionally comprises providing a fourth Airy etalon in ratio with the calibration etalon filter with conventional Airy function third Airy etalon to provide a common maximum at the limited number of wavelengths for a more defined optical transmitted bandwidth.
- 62. (Previously presented) A method as claimed in claim 58, for measuring infrared or visible wavelengths.
- 63. (Currently Amended) A computer program - readable medium comprising code means which when run on a computer cause the performance of for performing all the steps of:
 - a) splitting the optical beam into first, second, third and fourth sub-beams;
 - b) presenting the first sub-beam to reference first photodetector means;
 - c) presenting the second sub-beam to coarse filter means having an output to second photodetector means;
 - d) presenting the third sub-beam to a first fine periodic filter having an output to third photodetector means;
 - e) presenting the fourth sub-beam to a second fine periodic filter having an output to fourth photodetector means, wherein the first fine periodic filter and the second fine periodic filter are in quadrature and have a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first fine periodic filter

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coincide with substantially linear ranges between peaks and troughs of the second fine periodic filter;

- f) using synchronized clock signal measurement means to read outputs from the first, second, third and fourth photodetector means;
- g) identifying from predetermined transmissivity-wavelength characteristics of the coarse filter means and the first and second photodetector means outputs a limited range of wavelength in which the wavelength of the optical beam lies, to determine from their predetermined transmissivity-wavelength sensitivities which of the first fine filter and the second fine filter has a greater sensitivity to wavelength in that limited range; and
- h) using predetermined transmissivity-wavelength characteristics of the first or second fine filter having the greater sensitivity in the limited range of wavelength and the corresponding third or fourth photodetector means output, corresponding to the fine filter means having the greater sensitivity, to determine the wavelength of the optical beam ~~when the program is run on one or more computers.~~

64. (New) An optical wavelength meter for measuring an optical wavelength of an optical beam comprising:

- a) coarse optical filter means and first optical power measurement means for measuring output of the coarse optical filter means and second optical power measurement means for measuring an unfiltered reference beam for coarse wavelength measurement;
- b) fine optical filter means comprising first and second periodic optical filters in quadrature having a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first filter coincide with substantially linear ranges between peaks and troughs of the second filter, and third and fourth optical power

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measurement means for measuring output of the first and second periodic optical filters in quadrature for fine wavelength measurement, respectively;

- c) beam splitting means for splitting the optical beam between the unfiltered reference beam and the coarse and fine optical filter means;
- d) synchronized clock signal measurement means for synchronized measurement of the output of the first, second, third and fourth optical power measurement means;
- e) processing means for determining the optical wavelength of the optical beam from a predetermined transmissivity-wavelength relationship of the coarse filter and the first and second optical power measurement means for coarse wavelength measurement and from predetermined transmissivity-wavelength relationships of the first and second periodic optical filters and at least one of the third and fourth optical power measurement means for fine wavelength measurement; and
- f) calibration filter means and calibration filter output power measuring means, wherein the calibration filter means comprises an etalon filter.

wherein free spectral range of the calibration etalon filter differs just sufficiently from the free spectral range of the periodic optical filters that the calibration etalon filter is in phase only at top, middle and bottom wavelengths of a range of measurements of interest to obtain co-incident or Vernier-like maximum power at those wavelengths.

65. (New) A method of determining wavelength of an optical beam comprising:

- a) splitting the optical beam into first, second, third and fourth sub-beams;
- b) presenting the first sub-beam to reference first photodetector means;

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- c) presenting the second sub-beam to coarse filter means having an output to second photodetector means;
- d) presenting the third sub-beam to a first fine periodic filter having an output to third photodetector means;
- e) presenting the fourth sub-beam to a second fine periodic filter having an output to fourth photodetector means, wherein the first fine periodic filter and the second fine periodic filter are in quadrature and have a finesse of substantially 2 and free spectral range of substantially 100 GHz, such that peaks and troughs of the first fine periodic filter coincide with substantially linear ranges between peaks and troughs of the second fine periodic filter;
- f) using synchronized clock signal measurement means to read outputs from the first, second, third and fourth photodetector means;
- g) identifying from predetermined transmissivity-wavelength characteristics of the coarse filter means and the first and second photodetector means outputs a limited range of wavelength in which the wavelength of the optical beam lies, to determine from their predetermined transmissivity-wavelength sensitivities which of the first fine filter and the second fine filter has a greater sensitivity to wavelength in that limited range; and
- h) using predetermined transmissivity-wavelength characteristics of the first or second fine filter having the greater sensitivity in the limited range of wavelength and the corresponding third or fourth photodetector means output, corresponding to the fine filter means having the greater sensitivity, to determine the wavelength of the optical beam;
- i) providing a calibration etalon filter with conventional Airy function transmitting only at a reference wavelength for calibration having a

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common maximum with the first and second fine periodic filters respectively at a limited number of wavelengths within range;

- j) providing a broadband light source; and
- k) calibrating the processed readout from fine periodic filters to the reference wavelength of the calibration etalon filter.

66. (New) A method as claimed in claim 65, wherein step b) alternatively comprises providing a tuneable laser tuned to the reference wavelength.

67. (New) A method as claimed in claim 65, wherein step a) additionally comprises providing a fourth Airy etalon in ratio with the third Airy etalon to provide a common maximum at the limited number of wavelengths for a more defined optical transmitted bandwidth.